



Part One: How to Perform Your Soil Characterization

Students will locate a soil characterization sample site and prepare materials for field work.

Soil Characterization Field Measurements Protocol

Students will dig a hole, describe the characteristics of the horizons in the soil profile, and take samples of each horizon for analysis in the lab.

Soil Characterization Lab Analysis Protocol

Students will prepare samples for lab analysis and perform bulk density, particle size distribution, pH, and soil fertility measurements.

Part Two: Soil Moisture and Temperature

Students will locate a soil moisture study site and choose a sampling strategy and measurement frequency.

Gravimetric Soil Moisture Protocol

Students will measure soil water content 12 times per year using one of three sampling strategies.

Optional Gypsum Block Soil Moisture Protocol

Students will install gypsum blocks at four depths, measure their conductivity daily, and develop a calibration curve to permit conversion of the conductivity values to soil water content.

Infiltration Protocol

Students will measure the rate at which water soaks into the ground as a function of time.

Soil Temperature Protocol

Students will measure near-surface soil temperature weekly near local solar noon and seasonally throughout the diurnal year.

Part One:

How to Perform Your Soil Characterization



Sample Sites for the Investigation

Each GLOBE school is expected to perform the Soil Characterization protocols for at least two study sites. These are the Soil Moisture Study Site (see *Part Two: Soil Moisture and Temperature*), and the Biology Study Site (see the *Land Cover/Biology Investigation*). At each location, students dig a hole and examine the soil. Obtaining a soil profile to a depth of at least one meter into the ground is preferred wherever possible. Since the Soil Characterization Protocols are done only once for each location, the sites for which they are performed are referred to in GLOBE as Soil Characterization Sample Sites.

In many places, the soil profiles will vary significantly across the 15 km x 15 km GLOBE Study Site. Characterizing soil profiles at locations other than the two required sites can provide important additional science data and educational opportunities, and you are invited to do them. There is no limit on the number of soil characterizations you may submit to the GLOBE Student Data Server.

Some special opportunities may exist within your GLOBE Study Site to view soil profiles without digging. Road cuts may expose soil profiles; these can be sampled and characterized, but you should obtain a fresh profile face by removing the weathered surface with a shovel before proceeding with your observations and samples. Excavation sites are often interesting and usable. As always, make sure to be safe, and obtain any permissions required.

Locating a Soil Characterization Sample Site

There are several options for exposing and sampling the soil at a Soil Characterization Sample Site:

- Dig a soil pit at least 1 meter deep and as big around as is necessary to easily observe all of the soil horizons from the bottom to the top of the pit,
- Use a road cut, excavation site, or other location where others have exposed at least the top 1 meter of soil,
- Use an auger to remove soil samples to a depth of 1 meter, or
- Use a garden trowel or shovel to sample only the top 10 cm of soil if digging to a depth of 1 meter is not possible.

Some parts of the Soil Characterization Field Measurement Protocol are different depending upon which of these methods you are using.

If you will be digging to expose a soil profile, the Soil Characterization Sample Site should be:

- Safe for digging. Check with local utility companies and maintenance staff to ensure that you do not dig into or disturb a utility cable, water, sewer, or natural gas pipe, or sprinkler irrigation system of some kind,
- Under natural or representative cover. Find a relatively flat location with natural vegetation,
- Relatively undisturbed. Keep at least 3 meters from buildings, roads, paths, playing fields, or other sites where soils may have been compacted or disturbed by construction, and
- Oriented so that the sun will shine on the soil profile to ensure that the soil characteristics are clear for both naked-eye observations and photography.

Preparing for the Field

Bulk Density Containers

If your students have access to a soil drying oven, then they will be able to measure the bulk density of the soil layers. If not, skip this section and continue with the other materials to prepare.

If you are digging a soil pit, doing a near surface measurement or using a soil face exposed by others (road cut, excavation, etc.):

- Obtain 15 soil cans (enough for 5 horizons) or 3 cans if you will only be doing a near surface measurement.
- Label each can.
- Determine the volume of each can by:
 - Filling each can to the top with water (as full as you can).
 - Pouring the water into a graduated cylinder and measure its volume in mL (equal to cubic centimeters).
 - Recording the result on the Bulk Density Data Work Sheet. The volume of water that fills the can is equivalent to the volume of the can.
- Once the volume has been measured, make sure the can is dry and poke a small hole in the bottom of the can with a nail, to allow air in the can to escape when soil is being pressed into the can.
- Weigh each can.
- Record each weight on the Soil Bulk Density Data Work Sheet.
- Provide a lid or other means to seal each can for transport of the samples from the field to the laboratory.

If you are using the auger technique:

- Obtain 15 soil containers (enough for 5 horizons). In choosing containers remember the following:
 - The opening of each container should be large enough so that you can easily transfer a soil sample from the auger to the container without losing any of it.
 - The soil sample will be dried using a soil drying oven, and the best approach

is to place the soil directly into the container in which it will be dried.

- Plastic bags have big openings, but they melt and the soil sample must be transferred to metal, glass, or other containers before drying in the oven. Transferring the soil sample provides an opportunity for some of the sample to be lost.
- The combined weight of your container and soil sample must not exceed the capacity of your scale or balance.
- Label each container.
- Weigh each container in which the soil will be dried.
- Record each weight on the Soil Bulk Density Data Work Sheet.
- Provide a lid or other means to seal each container for transport of the samples from the field to the laboratory.

Other Materials to Prepare

Fill a small acid bottle with distilled white vinegar to test for free carbonates.

Fill squirt bottles with water (it need not be distilled).

Make a clinometer if you do not already have one. See the *Land Cover/Biology Investigation*.

Soil Characterization Field Measurements Protocol



Purpose

- To characterize the soils at the selected sites
- To obtain additional site information
- To gather samples from each horizon in order to perform later soil tests in the classroom

Overview

This protocol is divided into five tasks. In the first task, students will expose a 1 meter deep soil profile and identify the soil horizons. When this is not possible, a sample 10 cm deep can be taken to use for characterization. In the second task, students characterize the horizons by observing seven properties of soil layers. The students then perform the *Infiltration Protocol*, obtain additional site information, and take soil samples to use in determining bulk density, soil particle size distribution, soil pH, and soil fertility. In the final task, soil samples will be taken to the classroom and the drying of the samples begun.

Time

- Preparation of materials - up to one class period
- Soil pit including digging – up to one school day
- Identifying horizons and taking samples from a soil pit - one or two class periods
- Exposing and characterizing the soil profile using an auger and sampling – one or two class periods
- Characterizing and taking a soil sample from 10 cm depth – one class period

Level

All

Frequency

Once at each of at least two sites (Soil Moisture Study Site and Biology Study Site).

Three samples of each horizon must be taken in the field for the *Soil Characterization Lab Analysis Protocol*.

Key Concepts

- Soil horizon
- Soil profile
- Color
- Texture
- Structure
- Consistence
- Free carbonates
- Bulk density
- Root distribution
- Soil measurements may be influenced by external factors such as land use, vegetation type, climate, parent material, and topography.
- Sampling procedures

Skills

- Describing soil characteristics
- Using a clinometer
- Describing a landscape
- Collecting samples
- Preparing samples for lab analysis

Materials and Tools

- Garden trowels
- Shovels
- Dutch or other auger (See *Toolkit* for specifications)
- Water bottle with squirt top (e.g. a well-rinsed dish-washing liquid bottle) or atomizer with a trigger for wetting soil)
- Plastic sheet, tarp, board, or other surface on which to lay out a soil profile removed using the auger
- Soil color book
- Nalgene acid bottle filled with distilled white vinegar

Bulk density sample containers (or other sample containers if your school is not equipped to do bulk density measurements)
 Block of wood
 Hammer
 Meter Stick or tape measure or chop sticks with metric units
 20 nails, golf tees, or chop sticks for marking lower and upper boundaries of horizons
 Soil Characterization Data Work Sheet
 Bulk Density Data Work Sheet
 Soil Characterization Information Sheet
 Pencils
 Water Proof Marker
 Clip boards
 Small towel for cleaning hands
 Plastic bags or sealable containers roughly one-liter in size for transporting soil samples

One roll of tape for sealing the sample bags, cans, or other containers
 A box, sack, or bucket for transporting soil samples to the classroom
 One waterproof marker for labeling the sample bags
 Clinometer for measuring slope (see *Land Cover/Biology Investigation*)
 A camera and color film or a digital camera for photographing the soil profile and landscape (slides are acceptable)
 GLOBE Science Notebooks

Preparation

Select the site, obtain permission to dig, prepare the bulk density containers, gather the other tools and materials, have the pit dug.

Prerequisites

Preliminary discussion of soil horizons, structure, color, consistence, texture, free carbonates, and bulk density

Preparation

Secure the Soil Characterization Data Work Sheet (one copy is enough for six horizons) on a clipboard.

Take along the Soil Characterization Information Sheet from the *Appendix* to help you take the field measurements, the MUC system pages including definitions (from the *Land Cover/Biology Investigation*), and your GLOBE Science Notebooks.

Assemble all the field measurement equipment:

- Digging equipment as appropriate: auger(s), shovel(s), garden trowel(s)
- Meter stick or tape measure with metric units
- Nails, chopsticks, golf tees, etc.
- Soil color book
- Squirt bottle(s) with water
- Acid bottle filled with distilled white vinegar

- Bulk density sample containers (or other sample containers if your school is not equipped to do bulk density measurements)
- Plastic bags or sealable containers roughly one liter in size for transporting soil samples
- Clinometer
- One roll of tape for sealing the sample bags, cans, or other containers
- A box, sack, or bucket for transporting soil samples to the classroom
- Hand towel(s)
- Pencils
- Waterproof marker(s)
- Camera
- GPS if available

In addition for the auger technique:

- Plastic bag, tarp, board, or other surface on which to lay out the soil profile
- Copies of the Bulk Density Data Work Sheet for the Auger Technique (one copy is needed for each horizon so have at least five copies available)



How to Expose and Identify Soil Horizons

Soil Pit Technique

With this technique, students (or others) expose the soil profile by digging a soil pit.

1. Dig a pit one meter deep and as big around as is necessary to easily observe all of the soil horizons from the bottom to the top of the pit. As soil is removed from the pit, place the soil from each horizon in a separate pile. After the observations have been made and samples taken, the soil should be returned in the opposite order in which it was removed (i.e. the soil taken from the bottom of the pit should go in first, etc.).
2. If you need help to dig the soil pit, call upon parents, other teachers, custodians, student athletes, and local agricultural service personnel.
3. Have students look at the side of the soil pit on which the sun shines most directly so that soil properties will be clearly visible.
4. Starting from the top of the profile and moving down to the bottom, observe the soil profile closely to identify where there are changes in the appearance of the soil face.
5. Look carefully for any distinguishing characteristics like different colors, roots, the size and amount of stones, small light or dark nodules (called *concretions*), worms or other small animals and insects, worm channels, and anything else that is noticeable. If the soil is very dry, wetting it with your squirt bottle may help to distinguish color difference between horizons.
6. Mark the location of each of these changes or boundaries by sticking a nail, golf tee, chop stick, or other marker into the soil face. Sometimes it is difficult to identify differences in horizons because the properties of the whole soil profile are very similar. In this case, there may be

only a few very thick horizons present. Do your best to record exactly what you observe in the field.

7. Measure the top and bottom depths for each horizon to the nearest cm and record them on Soil Characterization Data Work Sheet.
8. If horizons are very thin, (<3 cm from top to bottom) do not describe them as separate horizons; combine them with the horizon above or below instead. Thin horizons should be noted in your GLOBE Science Notebooks. Students who wish to do so can identify the horizons by letter name using the descriptions given in the Introduction Section.
9. Proceed to characterize the properties of each of the soil horizons identified. Perform this characterization as soon as possible after the pit is dug.
10. Once this protocol is completed, students should fill in the pit with the original soil. If there are educational or other reasons why the pit is not refilled immediately, take appropriate precautions to ensure that the pit is not a hazard.

Existing Exposed Soil Profiles (a road cut, excavation, etc.)

1. Obtain permission to take samples from the road cut, excavation, or other soil profile exposed by others. Obey any and all safety precautions requested.
2. Expose a fresh soil face by scraping the soil profile with the edge of the garden trowel or other digging tool to remove the surface layer.
3. Perform Steps 4 - 10 as given for the Soil Pit Technique.

Auger Technique

With this technique, students display the vertical soil profile on a horizontal surface (the ground). Be sure to use the correct auger for your site. A Dutch auger, as described in the *Toolkit* is best for most soil, especially for rocky, clayey, and dense soils. A sand auger is needed if your soil is very sandy in texture. In some places, the soil is mostly



peat and a special peat auger should be used. A bucket auger may be better for dry, desert soils.

1. Identify an area where you can dig four auger holes where the soil profiles should be similar.
2. Spread a plastic sheet, tarp, board, or other surface on the ground next to where you will dig your first hole.
3. Assemble a profile of the top 1 meter of the soil by removing successive samples from the ground with the auger and laying them end-to-end as follows:
 - 3.1. Turn the auger one complete revolution (360°) to dig into the ground.
 - 3.2. Remove the auger with the sample in it from the hole.
 - 3.3. Hold the auger over the plastic sheet, tarp, or board.
 - 3.4. Transfer the sample from the auger to the plastic sheet, tarp, or board as gently as possible. Place the top of this sample just below the bottom of the previous sample.
 - 3.5. Measure the depth of the hole. Adjust the sample on the plastic bag, tarp, or board so that its bottom is no further from the top of the soil profile than this depth.
4. Starting from the top and moving down to the bottom, observe the soil profile closely to identify where there are changes in the appearance of the soil.
5. Look carefully for any distinguishing characteristics like different colors, roots, the size and number of stones, small light or dark nodules (called *concretions*), worms or other small animals and insects, worm channels, and anything else that is noticeable.
6. Mark the location of each of these changes or boundaries by sticking a nail, golf tee, chop stick, or other marker into the soil profile you have constructed. Sometimes it is difficult to identify differences in horizons because the properties of the whole soil profile are very similar. In this case, there may be only a few very thick horizons present. Do your best to record exactly what you observe in the field.

7. Measure the top and bottom depths for each horizon to the nearest cm and record them on Soil Characterization Data Work Sheet(s).
8. If horizons are very thin, (<3 cm from top to bottom) do not describe them as separate horizons, but combine them with the horizon above or below instead. Thin horizons should be noted in your GLOBE Student Data Notebook. Students who wish to do so can identify the horizons by letter name using the descriptions given in the *Introduction* section.
9. Proceed to characterize the properties of each of the soil horizons identified. Perform this characterization as soon as possible after the hole is augered.
10. Once these tasks are completed, where ever possible, students should fill in the hole with the original soil.

Near Surface Sample Technique

1. In situations where it is not possible for you to expose the top meter of soil, an additional option is to use the top 10 cm of the soil as a single horizon sample for soil characterization.
2. Use a garden trowel or shovel to carefully remove the top 10 cm of the soil from a small area and set it on the ground.
3. Treat this sample as a horizon and proceed to characterize its properties.

How to Observe and Record Soil Properties

For each horizon identified, the following characteristics should be observed, recorded on the Soil Characterization Data Work Sheet, and reported to the GLOBE Student Data Server using the Soil Characterization Data Entry Sheet. Note: The soil characteristics should be observed in the order given.

1. Soil Structure

Take a sample of undisturbed soil in your hand (either from the pit or from the shovel or auger). Look closely at the soil in your hand and examine its structure. Soil structure is the shape that the



soil takes based on its physical and chemical properties. Each individual unit of natural soil structure or aggregation is called a *ped*. Possible choices of soil structure are granular, blocky, platy, columnar, and prismatic, and are shown in Figures SOIL-P-1 to 5.



Sometimes your soil may be structureless, which means that within a horizon, soil peds have no specific shape. In this case, the soil structure is either single grained or massive. Single grained is like sand at a beach or in a playground where there are individual sand particles that do not stick together. Massive is when the soil sticks together in a large mass that does not break in any pattern. These conditions are more commonly found in C horizons, the horizons in which the parent material is least altered. Since the parent material has not yet undergone any weathering, it usually has not developed any structure.



It is common to see more than one type of structure in a soil sample. Students should record on their data sheets only the structure type that is

most common in their sample. They should discuss and agree upon the structure types they see. If the sample is structureless, record whether it is single-grained or massive.

2. Soil Color

Take a ped from the horizon and note on the data sheet whether it is moist, dry, or wet. If it is dry, moisten it slightly with water from your water bottle. Break the ped and hold the color chart

Figure SOIL-P-3: Granular Structure



Figure SOIL-P-1: Blocky Structure

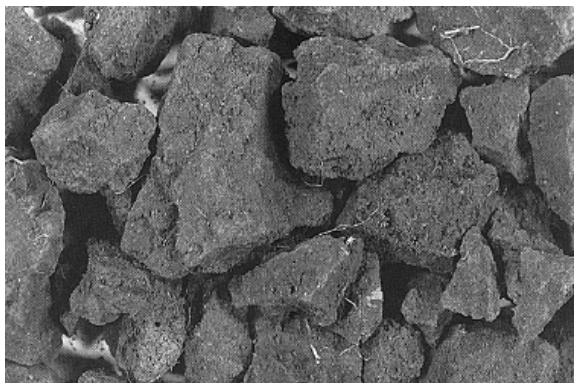


Figure SOIL-P-4: Platy Structure



Figure SOIL-P-2: Columnar Structure



Figure SOIL-P-5: Prismatic Structure



next to it. Find the color from the color chart which most closely matches the color of the inside surface of the ped. Stand with the sun over your shoulder so that sunlight shines on the color chart and the soil sample you are examining. Record on the data work sheet the symbol of the color on the chart that most closely matches the soil's color.

Sometimes, a soil sample may have more than one color. Record a maximum of two colors if necessary, and indicate (1) the dominant (main) color, and (2) the sub-dominant (other) color. Again, students both inside and outside the pit should agree on the choice of color.

3. Soil Consistence

Take a ped from the soil horizon. Record on the data work sheet whether the ped is moist, wet or dry. If the soil is very dry, moisten the face of the profile by squirting water on it, and then remove a ped for determining consistence. Holding the ped between your thumb and forefinger, gently squeeze it until it pops or falls apart. Record one of the following categories of soil ped consistence on the data sheet.

Loose: You have trouble picking out a single ped and the structure falls apart before you handle it.

Friable: The ped breaks with a small amount of pressure.

Firm: The ped breaks when you apply a good amount of pressure and the ped dents your fingers before it breaks.

Extremely Firm: The ped can't be crushed with your fingers (you need a hammer!)

4. Soil Texture

The texture of a soil refers to the amount of sand, silt, and clay in a soil sample, and the composition of these determines the way the soil feels when you rub it between your fingers. The texture differs depending on the amount of sand, silt, and clay in the soil sample. Sand particles are the largest with sizes up to 2 mm while clay particles are smaller than .002 mm. Particles greater than 2 mm are called stones or gravels and are not considered to be soil material. Even though they are small, the differences among sand, silt, and

clay particles can be felt, and each has its own characteristics. Sand feels gritty, silt feels smooth, and clay feels sticky. Usually a combination of these different size particles is found in a soil sample. Soil scientists use charts called textural triangles to help determine what percent of sand, silt, and clay are in a soil. Using Textural Triangles 1 and 2 to help you, follow these steps to identify your soil's texture.

4.1. Take a sample of soil about the size of a small egg and add enough water to moisten it. Work it between your fingers until it is the same moisture throughout. Then, squeeze it between your thumb and forefinger in a snapping motion to try to form a ribbon of soil.

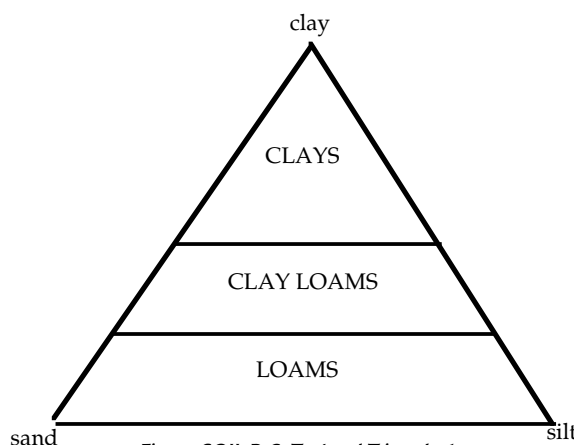


Figure SOIL-P-6: Textural Triangle 1

4.2. If the soil feels extremely sticky (sticks to your hands and is hard to work), stiff and requires a lot of thumb and finger pressure to form a ribbon, it is likely composed of mostly clay size particles. Classify it as a clay, as shown on Textural Triangle 1.

4.3 If the soil feels sticky and a little softer to squeeze, it probably has fewer clay particles. Classify it as a clay loam.

4.4 If the soil is soft, smooth, and easy to squeeze, and is at most slightly sticky, classify it as a loam.

Once the soil has been classified as clay, clay loam, or loam, refine the classification by determining the relative amounts of sand and silt.

4.5 If the soil feels very smooth, with no sandy grittiness, add the word "silt" or

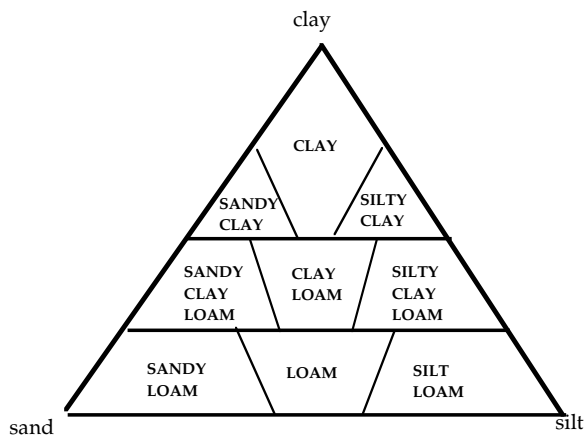


Figure SOIL-P-7: Textural Triangle 2

“silty” to your classification, such as “silty clay”, or “silty loam”, as shown on Textural Triangle 2. This means that your soil sample has more silt-size particles than sand-size particles.

4.6 If the soil feels very gritty, add the term “sandy” to your soil classification, such as “sandy clay”. This means your soil sample has more sand size particles than silt size particles.

4.7 If the soil feels neither very gritty nor very smooth, even if you can feel some sand in your sample, keep your original classification unchanged. This means your soil sample has about the same amounts of sand and silt size particles, and in the case of a clay, it may have very few of either.

Note: When feeling the soil texture, try to add the same amount of water to each sample so that you can more accurately compare one texture to the other. The soil texture can feel differently depending on how wet or dry it is. The amount of organic matter in the soil can also change how it feels. Generally, the darker the soil color is, the more organic matter is in it.

4.8 Record on the data work sheet the name of the soil texture that the students agree on. Also, note whether the sample was dry, wet, or moist when it was examined, and whether it contained a lot of organic matter (for instance if it was on the surface and had a very dark color).

5. Presence of Roots

Observe and record if there are none, few, or many roots in the horizon.

6. Presence of Rocks

Observe and record if there are none, few, or many rocks or rock fragments in the horizon. A rock or rock fragment is defined as being larger than 2 mm in size.

7. Test for Free Carbonates

Perform this test by squirting vinegar on the soil. If carbonates are present, there will be a chemical reaction between the vinegar, and the carbonates to produce carbon dioxide. When carbon dioxide is produced, it bubbles or *effervesces*. The more carbonates that are present, the more bubbles (*effervescence*) you will observe.

7.1. Look carefully at your soil profile for white coatings on the soil and rocks which might indicate that free carbonates are present.

7.2. Set aside a portion of the pit, exposed soil face, or sample from the auger hole or near surface which you do not touch with your hands, and use it for the free carbonates test.

7.3. After you have finished characterizing the other soil properties, test for free carbonates. Open the acid bottle and starting from the bottom of the profile and moving up, squirt vinegar on the soil particles. Look carefully for the presence of effervescence.

7.4 Record one of the following as the results of the Free Carbonate Test for each horizon:

None: if you observe no reaction, the soil has no free carbonates present.

Slight: if you observe a very slight bubbling action; this indicates the presence of some carbonates.

Strong: if there is a strong reaction (many, large bubbles) this indicates that many carbonates are present.

7.5. Do not bring samples contaminated with the vinegar back to the classroom.

Obtain Additional Site Information

At the same time that students take their soil characterization measurements in the field, or within a few months thereafter, spend some time with your class describing and recording details about your site.

1. Measure and record the GPS coordinates of your site.
2. Perform the *Infiltration Protocol* for three places near your soil pit, auger hole, or surface sample, or above the road cut or other excavation. You do not need to measure infiltration on more than one day; the day you are collecting the other soil characterization data is usually a good day to take this measurement.

3. Photograph the soil profile that has been described. Do this on the day measurements are taken in the field.

If students have exposed the soil profile by digging a soil pit or have used an existing exposed soil profile, place a tape measure or meter stick along the profile with the 0 cm mark at the ground surface.

Photograph the profile face from outside the pit, preferably with the sun behind the photographer shining on the exposed profile.

If the soil profile was obtained with an auger, photograph the soil profile lying on the paper or board on the ground with a tape measure or meter stick lying next to it. Again, have the 0 cm mark at the top or ground surface level of the profile, and have the sun behind the photographer.

In either case, take another photograph of the landscape around the Soil Characterization Sample Site.

Send copies of these photographs to the GLOBE Student Data Archive at the address given in the Implementation Guide, or if they were taken with a digital camera, submit them to the GLOBE Student Data Archive electronically.

4. Measure the slope of the sample site using the clinometer from the *Land Cover/Biology Investigation*, and record the slope

measurement on the Soil Characterization Data Work Sheet.

4.1 Designate two students whose eyes are at about the same height to measure the slope.

4.2 Measure the steepest slope that crosses the hole.

4.3 The student that holds the clinometer stands down slope and the other walks to the opposite side of the hole.

4.4 Looking through the clinometer, one student sites the eye level of the other student.

4.5 Read the angle of slope in degrees and record this reading on the data work sheet.

5. Measure and record the distance from major features (such as buildings, power poles, roads, etc.).
6. Record any other distinguishing characteristics that make this site unique. (While all of the following data will not be reported to GLOBE at the current time, such data should be recorded in the school's local database.)
Questions you might ask are:
 - What are the types of plants and animals you find in the soil and the general area around your site? Include small organisms in the soil such as earthworms or ants.
 - What is the parent material from which the soil was formed? Was it bedrock? If so, look for rocks on the surface to tell you something about the kind of rock. Could your soil have been deposited by water or wind, by a glacier or volcano? If necessary, further investigate the surface geology of your area in your local library.
 - Where in the landscape is your soil? Is it on a hilltop, slope, or bottom of a hill? Is it next to a stream or on a flat plain? On what kind of land form is it found?
 - What is the general climate at your soil site? Is it sunny, shaded, hot, cold, moist, dry?
 - What is the recent land use in this area? Has it been stable for a long time, or has it been plowed, its trees cut, used for



construction, or undergone some other disturbance recently?

7. Record all requested information on the Soil Characterization Data Work Sheet.

Information about your site and data collection techniques (often called metadata) should be entered permanently in your GLOBE Science Notebook and registered with your site using the Soil Characterization Sample Site Data Entry Sheet. You are not required to enter all this information, but it is of great help to scientists and others who want to use these data. A sample site must be defined before the soil characterization data for it can be entered. Initially, this definition can consist of no more than a name for the site and the date on which the field observations were made and the soil samples taken. As more information becomes available to characterize the sample site, these data can be added to the GLOBE Student Data Archive using the modify a sample site procedure.

Soil Sampling

The methods for obtaining soil samples for further analysis are different depending on how you have exposed your soil profile.

Soil Pit Technique and Existing Exposed Soil Profiles

Taking Bulk Density Samples

1. For each horizon in your soil profile, push a can with a known volume into the side of the horizon. The soil in the profile should be moist, so that it will stick together and so that the can will go in easily. If necessary, wet the soil before doing this measurement.
2. If it is still difficult to push the can into the soil, you may need to use a hammer or other object to force it in. If this is necessary, place a piece of wood over the can and hit the wood with the hammer to spread the force of the hammer blow to all edges of the can at once and to minimize denting the can.

Note: Some denting is allowed in this procedure as long as the volume of the can is not changed by more than a few percent, but if the can dents too badly, the

soil may be too hard or rocky to take a bulk density sample this way. You might consider taking a bulk density sample using the auger method described below, instead, for the dense horizons.

3. Stop when you can see some of the soil poking through the small hole in the bottom of the can, the can has been filled with soil.
4. Using a trowel or shovel, remove the can and the soil surrounding it. Trim the soil from around the can until it is flat against the edges of the can so that the volume of the soil is the same as the volume of the can.
5. Cover the can with the lid or other cover and return it to the classroom.
6. Repeat this procedure so that you have 3 bulk density samples for each horizon.
7. Label the cans in the field with the site name, horizon number (or letter), top and bottom depths, and sample number (1, 2 or 3 for each horizon).
8. Bring these samples in from the field as soon as possible.
9. Remove the covers.
10. Weigh each sample in its can and record this moist weight on the Bulk Density Data Work Sheet.
11. Place the samples in the soil drying oven.

If you are not measuring bulk density:

1. Dig an ample sample from each soil horizon. Avoid the area of the soil face which was tested for carbonates and avoid touching the soil samples so that your pH measurements will not be contaminated.
2. Place each sample in a bag or other soil container.
3. Label each bag with the site name, horizon number (or letter), and top and bottom depths.
4. Bring these samples in from the field.
5. Spread the samples on separate plastic plates or sheets of newspaper to dry in the air.



Auger Technique

Three samples are needed from each horizon. Each will be obtained from a new auger hole.

Taking Bulk Density Samples:

For each auger hole:

1. Auger to a depth 1 or 2 cm past the top of the horizon to be sampled.
2. Measure the depth of the hole.
3. Use the auger to remove a sample of the horizon. If the horizon has a smaller vertical extent than the length of the auger head, only perform a partial turn of the auger so that the whole sample will be from just this horizon. Do not turn the auger more than one complete circle (360°) so that the soil does not become compacted.
4. Once the sample is removed, transfer all the soil from the auger head to a sample container without losing any on the ground. Avoid handling the sample as much as possible to minimize the soil contamination by natural oils from your skin.
5. Measure the diameter of the hole that the auger made, and the depth of the hole.
6. Label the outside of the container with the horizon name, the diameter of the hole, and depth of the hole before and after this sample was removed. (These measurements will be used to calculate the volume of the sample.)
7. Repeat steps 1 - 6 for each horizon in the soil profile.
8. Repeat this procedure in different holes, next to each other, so that you obtain 3 samples of each horizon.
9. Cover or seal the samples and transport them to the classroom.
10. Bring these samples in from the field as soon as possible.
11. Remove the covers.
12. Weight each sample in its container and record this moist weight on the Bulk Density Data Work Sheet.
13. Place the samples in the soil drying oven.

If you are not measuring bulk density:

For each auger hole:

1. Auger to a depth 1 or 2 cm past the top of the horizon to be sampled.
2. Use the auger to remove a sample of the horizon. If the horizon has a smaller vertical extent than the length of the auger head, only perform a partial turn of the auger so that the whole sample will be from just this horizon.
3. Place the sample in a bag or other soil container. Avoid contaminating the sample by touching it with your hands.
4. Label each bag with the site name, horizon name, and top and bottom depths of the horizon.
5. Repeat Steps 1 - 4 for each horizon.
6. Bring these samples in from the field. Spread the samples on separate plastic plates or sheets of newspaper to dry in the air.

Near Surface Sample Technique

Taking Bulk Density Samples:

1. Choose 3 locations close to the location where you performed your *Soil Characterization Protocol*.
2. Remove vegetation and other material from the soil surface.
3. For each of the 3 locations:
 - 3.1. Push a can with a known volume into the surface of the soil. The soil in the profile should be moist, so the soil will stick together, and the can will press into the ground easily. If necessary, wet the soil before doing this measurement. Let the moisture seep into the soil before sampling. It is preferable to sample moist soils and not wet soils unless the soil is naturally saturated with water.
 - 3.2. Stop when you can see some soil poking through the small hole in the bottom of the can, you have filled the can.
 - 3.3. If it is difficult to push the can into the soil, you may need to use a hammer or other object to force it in. If this is



necessary, place a piece of wood over the can and hit the wood with the hammer to spread the force of the hammer blow to all edges of the can at once and to avoid denting the can.

3.4. Slide a trowel or shovel under the can and the soil surrounding it and lift it out carefully. Trim the soil from around the can until it is flat against the edges of the can so that the volume of the soil is the same as the volume of the can.

3.5. Cover the can with the lid or seal it for transport back to the classroom.

3.6. Label the cans in the field with the site location and the number of the sample (i.e. 1, 2 or 3).

4. Bring these samples in from the field as soon as possible.

5. Remove the covers.

6. Weigh each sample in its can and record this moist weight on the Bulk Density Data Work Sheet.

7. Place the samples in the soil drying oven.

If you are not measuring bulk density:

1. Dig an ample sample from the top 10 cm of the soil. Avoid the area which was tested for carbonates, and avoid touching the soil samples so that your pH measurements will not be contaminated.
2. Place each sample in a bag or other soil container.
3. Label each bag with the site name, horizon name, and top and bottom depths.
4. Bring these samples in from the field.
5. Spread the samples on separate plastic plates or sheets of newspaper to dry in the air.

Soil Characterization Lab Analysis Protocol



Welcome

Introduction

Protocols

Learning Activities

Appendix

Soil Characterization Field Measurements

Purpose

To determine the bulk density of the soil

To determine the soil particle size distribution

To measure soil pH

To determine soil fertility by measuring the amounts of nitrate nitrogen, phosphorus, and potassium (N, P, K) in the soil

Overview

In the classroom/laboratory, students will dry the bulk density samples in an oven, weigh them, sieve them to remove rocks, and determine the weight and volume of the rocks. The sieved bulk density or other samples will be used to determine the particle size distribution, the soil pH, and the soil fertility (N, P, K).

Time

For drying soil samples, allow at least 10 hours for drying at 95 - 105 ° C, 24 hours for drying at 75 - 95 ° C, or two days for air drying (no classroom time is involved).

Preparation of dispersing solution needed prior to class - 10 minutes

Dispersing step for Particle Size Distribution procedure, sieving dry samples and completing the bulk density measurement - one class period

2 and 12 minute measurements for Particle Size Distribution, and measurements of Soil pH and Soil Fertility - one class period

Final Particle Size Distribution measurement, clean up, and review of all the data - one class period

Level

Soil Fertility (N, P, K) — Intermediate and Advanced.

Other measurements — All

Frequency

Once for each horizon

Three samples for each horizon

Key Concepts

Volume

Density

Bulk density

pH of soil

Soil fertility (N, P, K)

Soil nutrients

Chemical reactions

Specific gravity

Particle size distribution

Texture

Supernatant

Skills

Handling samples

Sieving samples

Recording data

Manipulating scientific equipment

Observing color

Pipetting

Measuring pH, specific gravity, and soil fertility

Determining relative nutrient content

Using a hydrometer

Materials and Tools

For Recording Data During All Measurements:

Bulk Density Data Work Sheet

Particle Size Distribution Data Work Sheet

pH Data Work Sheet

Soil Fertility Data Work Sheet

For Drying and Sieving Samples:

Newspapers or plastic plates

#10 sieve (2 mm mesh openings)



Liter-size bags, jars, or containers for storing soil samples

Balance

Rubber gloves

For Bulk Density

Drying oven or microwave

100 mL graduated cylinder to determine volume of rocks

Balance

For Particle Size Distribution:

Rolling Pin, hammer, or other utensil for crushing peds and separating particles

500 mL clear plastic graduated cylinder

Hydrometer

Thermometer (needs to have a smooth surface without a cover so that soil and water do not get trapped)

Spoon or other utensil to transfer soil

Spoon or stirring rod for stirring soil

Dispersing solution (50 g Sodium Hexametaphosphate/liter or non-sudsing powdered detergent containing sodium and phosphate)

250 mL or larger beaker

Squirt bottle for washing soil out of beaker

Stop watch or a clock with a second hand
Plastic Wrap or other material to cover top of cylinder during shaking

1 L bottle for dispersing solution

For pH:

Three 100 mL-beakers

Balance

pH paper, pen, or meter

Glass stirrer or spoon

Distilled water

100 mL-graduated cylinder to measure distilled water

For Soil Fertility:

Distilled water

Soil Fertility Kit with reagents to measure N, P, and K

Teaspoon

Cup or test tube rack to hold tubes

For Disposing of Soil:

Buckets or other large water tight containers

Preparation

Calibration of pH meter or pen

Prerequisites

Soil Characterization Field Measurement

How to Measure Bulk Density and Prepare Samples for Other Lab Analyses

Bulk Density

1. Dry the samples in their containers following the directions given for drying samples in the *Gravimetric Soil Moisture Protocol*.
2. Weigh each dry bulk density sample in its container and record this dry weight on the Bulk Density Data Work Sheet.
3. Rocks don't hold water or store nutrients, so they don't contribute to the bulk density of soil.

To determine the density of any rocks that are in a sample use the following procedure (if there are no rocks in your sample, skip this part):

3.1 Place a large piece of paper (such as newspaper) on a table and put the #10 (2 mm openings) sieve on top of it. Pour one sample into the sieve.

3.2 Put on rubber gloves to avoid contaminating your sample with acids from your skin.

3.3 Carefully push the dried soil material through the mesh onto the paper. Do not force the soil through the sieve as this may bend the mesh openings. Rocks will

not pass through the mesh and will stay on top of the sieve. If no sieve is available, carefully remove the rocks by hand.

3.4 Save the sieved soil from each sample for the other lab analyses.

3.5 Weigh the rocks, and record this weight on the Bulk Density Data Work Sheet.

3.6 Place 30 mL of water in a 100 mL graduated cylinder, and without spilling, add the rocks to the water. Read the level of the water after all the rocks have been added and record this value and the original volume of water on the Bulk Density Data Work Sheet.

As you add the rocks, if the volume of the water comes close to 100 mL, record the increase in volume, empty the cylinder and repeat the procedure for the remaining rocks. In this case, you must calculate and record the sum of the water volumes with the rocks and the sum of the water volumes without the rocks.

Making Sense of the Data

When you are done, the following should have been recorded on your Bulk Density Data Work Sheet and reported to the GLOBE Student Data Server using the Bulk Density Data Entry Sheet:

- the volume of the soil can (mL) (For the pit or surface sampling method)
- the weight of the soil can (g) (For the pit or surface sampling method)
- the diameter of the hole (cm) (For the auger method)

- the top and bottom depth of the hole (cm) (for the auger method)
- the weight of the container (g) (for the auger method)
- the weight of the moist soil and container (g) (only needed if you wish to calculate soil water content)
- the weight of the dry soil and container (g)
- the weight of the rocks (g)
- the volume (or sum of the volumes) of the water added to the graduated cylinder before rocks are added (mL)
- the volume (or sum of the volumes) of the water after rocks have been added (mL)

To calculate soil water content:

In doing the bulk density measurements, if you measured the weight of the moist soil and container you have obtained all the information needed to determine the soil water content of your sample. If you wish to know the soil water content, follow the procedures for this calculation given in the *Gravimetric Soil Moisture Protocol*. These soil water content values are not reported to GLOBE; they are only for student practice and added insight.

If you are not measuring bulk density

Prepare the samples for the lab analyses.

1. Place a large piece of paper (such as newspaper) on a table.
2. Put the #10 (2 mm openings) sieve on top of it.

The bulk density of the soil material (in units of g/cm³) can now be calculated for each sample by:

$$\text{Bulk density} = \frac{\text{dry weight} - \text{container weight} - \text{weight of rocks}}{\text{container or hole volume} - \text{volume of rocks}}$$

$$\text{Hole volume} = \pi \times \left[\frac{\text{hole diameter}}{2} \right]^2 \times [\text{bottom depth of hole} - \text{top depth of hole}]$$

$$\text{Volume of rocks} = \text{volume of water and rocks} - \text{volume of water before rocks were added}$$

If you had to measure the volume of rocks in more than one batch, add the volumes calculated for each batch to get the total volume of rocks.



3. Pour the sample into the #10 sieve. Put on rubber gloves so the acids in your skin don't contaminate the soil pH measurement.
4. Carefully push the dried soil material through the mesh onto the paper. Do not force the soil through the sieve or you may bend the wire mesh openings. Rocks will not pass through the mesh and will stay on top of the sieve. Remove the rocks (and other pieces of debris) from the sieve and discard. If no sieve is available, carefully remove the rocks and debris by hand.
5. Transfer the rock-free, dry soil from the paper under the sieve into new, clean, dry plastic bags or containers.
6. Seal the containers, and label them the same way that they were labeled in the field (horizon name, top and bottom horizon depth, date, site name, site location). This is the soil that will be used for the other lab analyses.
7. Store these samples in a safe, dry place until they are used.

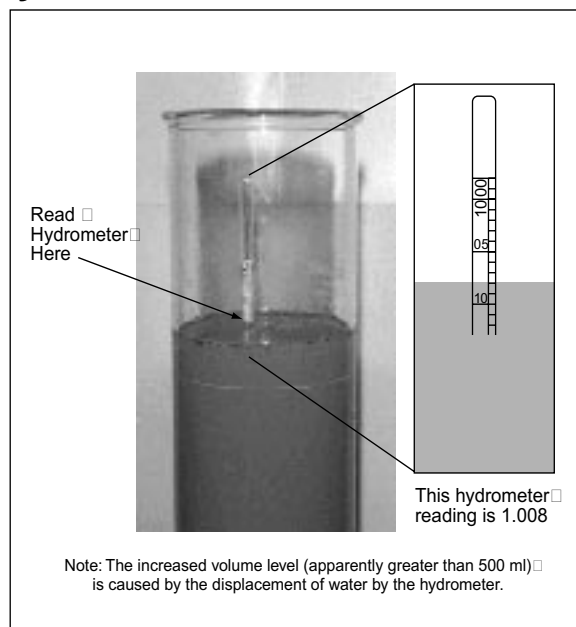
How to Measure Soil Particle Size Distribution

Repeat this measurement three times for each horizon, and record all sets of data on the Particle-Size Distribution Data Work Sheet.

1. Prepare the dispersing solution by mixing 50 g of Sodium Hexametaphosphate (or other material as indicated above), in 1 L of distilled water. Dissolve all of the solid material by stirring the mixture.
2. After drying and sieving the soil samples, use a rolling pin, mortar and pestle, or hammer to break up any large particles that might still be present.
3. Weigh 25 grams of dried, sieved soil and pour it into a 250 mL or larger beaker. Pour 100 mL of the dispersing solution and about 50 mL of distilled water into the beaker. Stir vigorously with a spoon or stirring rod for at least one minute. Be sure the soil is thoroughly mixed and does not stick to the bottom of the beaker. Do not spill any of the soil suspension.

4. When the soil and dispersing solution are thoroughly mixed, rinse any soil left on the stirrer into the beaker with the rest of the mixture. Set the beaker aside in a safe place and allow it to sit for about 24 hours (the sample can be left to mix with the dispersing solution over the weekend as well).
5. While the suspension is sitting, put a meter stick or other ruler in the cylinder and measure the distance between the 500 mL mark and the bottom of the cylinder. Also read the temperature at which your hydrometer has been calibrated (such as 15.6° C or 20° C). This number will be found somewhere on the hydrometer. Record both on the Particle Size Distribution Data Work Sheet.
6. After roughly 24 hours (or during the same class period the next school day), stir the suspension in the beaker again, and pour it into a 500 mL graduated cylinder.
7. Using a squirt bottle, rinse out the beaker with distilled water, and add this to the soil mixture in the cylinder.
8. Add enough distilled water to fill the cylinder to the 500 mL mark.
9. Securely cover the top of the cylinder using plastic wrap or another secure cover.

Figure SOIL-P-8



10. Mix vigorously by rotating the covered cylinder hand-over-hand at least 10 times. Be sure the soil is thoroughly mixed in the solution and does not stick to the bottom of the cylinder. Also, try not to let any of the soil suspension leak out the top.
11. Gently set the cylinder down in a safe place, and immediately begin timing with a stop watch or clock with a second hand.
12. Record the time that the cylinder was set down to the second.
13. After 1½ minutes, carefully lower (do not drop) the hydrometer into the cylinder and allow it to float in the soil suspension. Steady the hydrometer to suppress its bobbing up and down.
14. Exactly 2 minutes after the cylinder was set down, read the line on the hydrometer that is closest to the surface of the soil suspension. See Figure SOIL-P-8.
Note: Read the hydrometer for the Soil Particle Size Distribution protocol the same way that is read for the *Salinity Protocol*.
15. Remove the hydrometer, rinse it, dry it, and gently put it down in a safe place.
16. Suspend the thermometer in the soil suspension in the cylinder for about 1 minute.
17. At the end of 1 minute, remove the thermometer from the suspension, read the temperature, and record the result on the Data Work Sheet.
18. Rinse the thermometer off and dry it.
19. Allow the cylinder to sit safely without being disturbed.
20. Take another hydrometer measurement in the undisturbed cylinder at 12 minutes. Place the hydrometer carefully in the suspension about 30 seconds before taking the reading to allow it to settle.
21. Take and record another temperature reading for the suspension.
22. Rinse the hydrometer and thermometer off when they have been removed from the suspension and dry them.
23. Record these results on the Particle Size Distribution Data Work Sheet.

24. Leave the cylinder undisturbed for 24 hours (or until the beginning of the same class period the next day). Note: this time period is critical and should not be significantly longer than 24 hours.
25. Take another hydrometer and temperature reading.
26. Record the results on the Data Work Sheet.
27. Discard the soil suspension by pouring it into a special pail, and spill the contents outside in a place for discarding soil materials. DO NOT pour the suspension down the sink!
28. Carefully rinse and dry the hydrometer, thermometer, beakers, and cylinders, and repeat the above steps 2 more times for the same horizon so that you have a total of 3 sets of results for this horizon.

Note: This measurement involves considerable waiting time and must be done for three samples from each horizon in the soil profile. The number of days required to complete the set of measurements depends on the amount of equipment available. After a sample is mixed with dispersing solution and water initially, it should stand for a day before proceeding to do the measurement, and after the first two measurements, the sample sits undisturbed for 24 hours more. If your soil profile has five horizons, this task must be done 15 times. If only one 500 mL cylinder is available, the measurement of all the samples must be spread out over many days. Having multiple 500 mL cylinders would allow you to accelerate this process. One hydrometer should be adequate for use with at least three cylinders if the starting times of the settling are staggered by about three minutes. However, a single 500 mL cylinder and hydrometer are adequate for use in the *Hydrology Investigation Salinity Protocol*, and if your students will be doing the soil characterization only a few times spread over several school years, then the same cylinder and hydrometer can be reused and the particle size distribution measurements spread over several weeks to save on equipment costs.



How to Measure pH

Make this measurement on three samples for each horizon.

Mix Soil and Distilled Water

1. In cup or beaker, mix dried and sieved soil with distilled water in a 1:1 soil to water ratio (e.g. mix 20 g of soil with 20 mL of water, mix 50 g of soil with 50 mL of water). Mix enough soil and water so that the pH reading can be made in the *supernatant* (the clearer liquid above the settled soil particles). Use a spoon or other utensil but not your hands to transfer the soil. Oils and other materials on your hands may contaminate the pH reading. Stir with a spoon or other stirrer until the soil and water are thoroughly mixed.
2. Stir the soil-water mixture every 3 minutes for 15 minutes. After 15 minutes, allow the mixture to settle until a supernatant forms (about 5 minutes).

With pH paper (Beginning Level):

1. In a cup or beaker, measure the pH of the water you are using for this protocol by dipping the pH paper into the water and comparing the color to the color chart (as described in the *Hydrology Investigation pH Protocol*).
2. Measure the pH of the supernatant by dipping the pH paper into it (following the procedure given for pH paper in the *Hydrology Investigation*).
3. Record your results on the Soil pH Data Work Sheet.

With the pH pen or meter (Intermediate and Advanced Levels):

1. Calibrate the pH pen or meter with the buffer solutions of known pH following the procedure outlined in the *Hydrology Investigation* for Calibration.
2. In a cup or beaker, measure the pH of the water you are using for this protocol by placing the pH pen or meter into the water and reading the value indicated.

Figure SOIL-P-9

Place the bottom of the pH pen in the Supernatant (the clearer liquid above the settled soil)



The pH of this soil is 6.5

3. To measure the soil pH, place the electrode of the pH pen or meter into the supernatant. See Figure SOIL-P-9.
4. Record your results on the Soil pH Data Work Sheet.

How to Measure Soil Fertility

Part 1: Preparation and Extraction

1. Fill the extraction tube from your Soil Test kit to the 30 mL line with distilled water.
2. Add 2 *Floc-Ex* tablets. Cap the tube and mix well until both the tablets have disintegrated.
3. Remove the cap and add one heaping spoonful of soil (about 5 mL).
4. Cap the tube and shake for one minute.
5. Let the tube stand until the soil settles out (usually about 5 minutes). The clear solution above the soil will be used for the nitrate nitrogen (N), phosphorus (P), and potassium (K) tests.

Note: For some soils, especially those with a high clay content, there may not be enough clear solution extracted. If more clear solution is needed, repeat Steps 1 - 5.



Part 2: Nitrate Nitrogen (N)

1. Use the pipette to transfer the clear solution above the soil to one of the test tubes in the Soil Test Kit until the tube is filled to the shoulder. (If there is not enough solution to fill the tube to the shoulder, repeat Part 1).
2. Add one Nitrate WR CTA Tablet. Sometimes the tablets may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Cap and mix until the tablet disintegrates.
3. Rest the test tube in a cup or beaker. Wait 5 minutes for color to develop. Do not wait longer than 10 minutes.
4. Compare the pink color of the solution to the Nitrogen Color Chart in the Soil Test Kit. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.
5. Discard the solution and wash the tube and the pipette with distilled water.
6. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Part 3: Phosphorus (P)

1. Use the clean pipette to transfer 25 drops of the clear solution above the soil to a clean test tube. (If there is not enough solution, repeat Part 1).
2. Fill the tube to the shoulder with distilled water.
3. Add 1 Phosphorus Tablet to the tube and cap it. Sometimes the tablets may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Mix until the tablet disintegrates.
4. Rest the test tube into a cup or beaker. Wait 5 minutes for color to develop, but no longer than 10 minutes.
5. Compare the blue color of the solution to the Phosphorus Color Chart in the Soil Test Kit. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.

6. Discard the solution and wash the tube and the pipette with distilled water.
7. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Part 4: Potassium (K)

1. Use the clean pipette to transfer the clear solution above the soil to a clean test tube until it is filled to the shoulder. (If there is not enough solution to fill the tube to the shoulder, repeat Part 1).
2. Add 1 Potassium Soil Tablet to the tube. Sometimes the tablet may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Cap and mix until the tablet disintegrates. Note: This tablet may take longer to dissolve than the others.
3. Compare the cloudiness of the solution in the test tube to the Potassium Color Chart in the Soil Test Kit. Hold the tube over the black boxes in the left column, and compare its shade and cloudiness to the shaded boxes in the right column. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.
4. Discard the solution and wash the tube and the pipette with distilled water.
5. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Data Submission

Record your data on the Bulk Density, Soil Particle Size Distribution, Soil pH, and Soil Fertility Data Work Sheets. More than one copy of a data work sheet may be required to describe a profile, so be sure to have extra copies. Staple together the sheets for the same soil profile so that records are kept together. Submit your findings to the GLOBE Student Data Server.

Part Two:

Soil Moisture and Temperature

Introduction

This section introduces material common to three standard protocols and a fourth optional protocol for advanced students. The protocols are all related to soil moisture and temperature. To begin, students will use a simple procedure to measure soil moisture. They will weigh a soil sample, dry it out, and weigh it again. The difference in weight is the moisture in the soil that was dried out. An optional protocol for advanced students involves the use of gypsum blocks and a soil moisture meter to take daily readings of soil water content. Two new protocols measure other important soil properties. The rate water flows into the soil (infiltration) is measured using two concentric cans. Soil temperature is measured using a short dial or digital probe thermometer.

Study Site for the Investigation

Generally, the Soil Moisture Study Site should be in the open, with no canopy overhead, and within 100 m of the Atmosphere Study Site or a supplemental Atmosphere Study Site with at least a rain gauge. Depending upon which sampling strategy is used (see below) you may need an area 10 m in diameter characterized by low slopes, homogeneous soil characteristics, natural soil moisture, and uniform sunlight conditions. It is useful to make soil characterization, soil temperature, and infiltration measurements within the same homogeneous 10 m area so that they can all be related to the soil moisture measurements. Some schools may choose a larger site with an area 10 m by 60 m which meets most of the criteria summarized above but which can include some variations in slope and other characteristics.

Your Soil Moisture Study Site(s) should be:

Unirrigated. Since we want to investigate the soil's response to the sun and natural precipitation, it is important that your site be unirrigated.

Uniform. Soil moisture can vary significantly across short distances. The challenge is to find an

area where the soil moisture is representative of your site. Look for a relatively flat site that has uniform soil properties and vegetation.

Relatively undisturbed. Sample soils at least three meters from buildings, roads, paths, playing fields, and other sites where the soil may be compacted or heavily disturbed by human activity.

Safe for digging. Check with local utility companies and site maintenance staff to ensure that you do not dig into or disturb a utility cable, buried pipe, or sprinkler irrigation system. You will not be digging below one meter.

Frequency

Measure soil moisture at regular intervals, twelve times each year. Select a period during which you would normally expect the soil at your study site to undergo significant moisture changes. Observations of soil moisture should not be made when the ground is frozen. Weekly measurements during the beginning of your dry season will help predict plant growth. Monthly observations throughout the year or measurements every three weeks during a nine or ten month school year will provide insight into important seasonal variations.

Take your observations at the same time every day, and avoid early morning when dew is present. Soil moisture changes slowly so that the time of your observations is not critical. Taking all the measurements at one time of day ensures that any small daily cycles, particularly in near surface soil moisture, will not confuse your weekly to monthly observations.

Measure soil temperature once per week and on the same date and at the same location as your soil moisture measurements. If your school is not measuring soil moisture, take soil temperature measurements within 10 m of your Atmosphere Study Site following the sampling strategy for temperature given under *Collecting in a Star Pattern*. Weekly temperature measurements should be taken within one hour of local solar

noon. Every three months, preferably during March, June, September and December, make soil temperature measurements every two to three hours during the daytime for two consecutive days to determine the diurnal temperature variation at your site.

Measure soil infiltration three times during the course of your annual soil moisture investigation, ideally around the beginning, middle and end of that observation period, and on the same day you sample soil moisture. If you measure soil moisture monthly, measure infiltration seasonally.

Sampling Strategies and Site Layout

Materials and Tools

GLOBE Science Notebooks and pencils
Compass and 50 meter tape
25 cm ruler, meter stick
Trowel

Collecting in a Star Pattern (6 containers)

Measurements are taken in a star-shaped pattern with samples collected each time at different locations on the star. Soil moisture samples will

come from a depth of 0 to 5 cm and at a depth of 10 cm. Each time, three samples should be acquired (1 primary sample and 2 additional samples within 25 cm) for quality control purposes. Take three soil temperature measurements at depths of 5 cm and 10 cm within 25 cm of the sampling point following the *Soil Temperature Protocol*.

Layout a simple star two meters in diameter by using a meter stick and compass to locate four points approximately one meter north, south, east and west from a central reference marker. Locate four more points halfway between these points along an imaginary circle connecting these points. You now have eight points on your star. Four more points should be located 25 cm from the reference marker along the north - south, east - west lines. Every year, select a new reference marker within ten meters of the previous year's star and repeat this pattern. It should take less than ten minutes to collect your six soil moisture samples using a trowel.

Collecting Along a Transect (13 containers, 50 m tape or cord marked every 5 m)

Students with access to an open, natural field are encouraged to take measurements along a transect. The soil samples will come from the top 5 cm of soil. Each time, thirteen samples will be acquired - ten regular samples along the transect and one triplicate sample (1 sample along the transect plus 2 additional samples within 25 cm of the first) for quality control purposes.

Layout your transect along a straight line 50 meters long across an open area within 100 m of a rain gauge, if possible. Measure soil moisture every five meters along this line. Place a permanent flag or marker at the ends of your transect. Use the knotted cord or a measuring tape to locate these sampling points. Orientation does not matter, but please record the orientation as a comment on the Study Site Work Sheet and report it on the Study Site Definition Data Entry Sheet. The next time you sample the transect, shift each of your data collection points 25 cm to avoid the previously disturbed area. It might take an hour to layout and sample a transect, especially if students are sharing equipment and observing other surface and soil characteristics.

Figure SOIL-P-10: "Star" Sampling Pattern

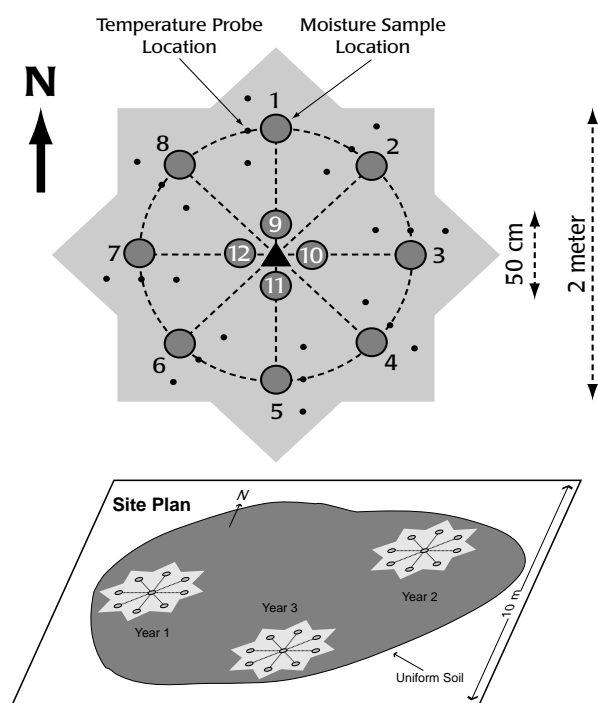
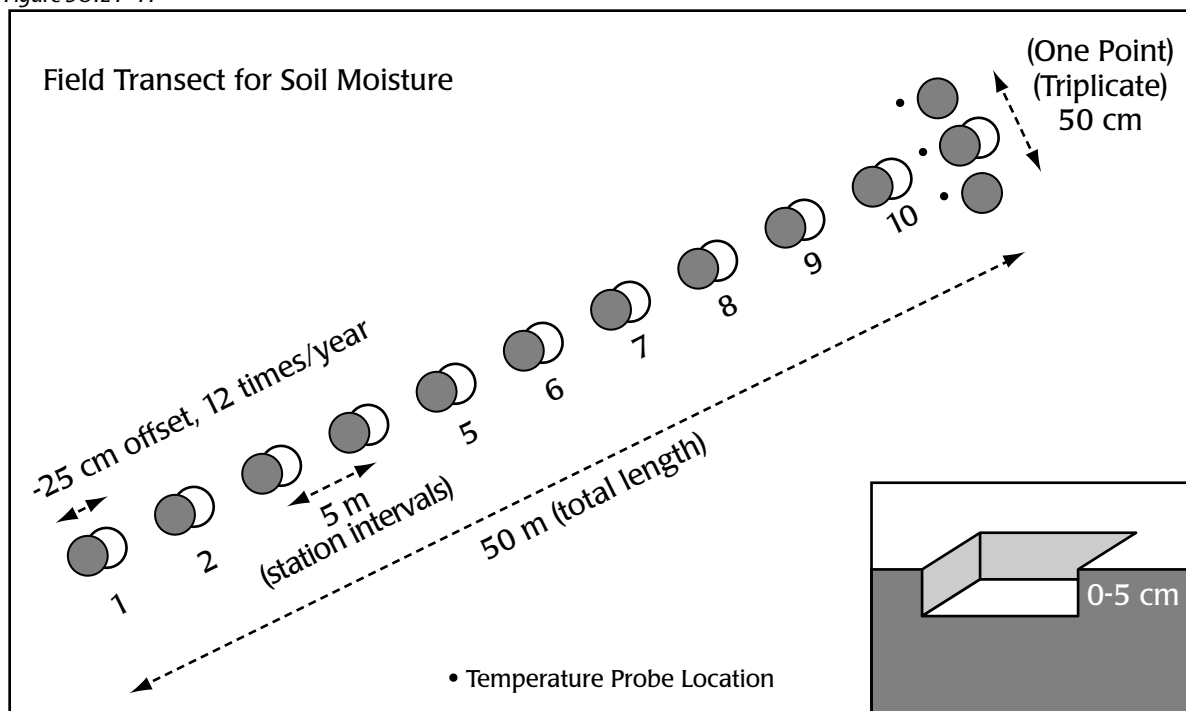
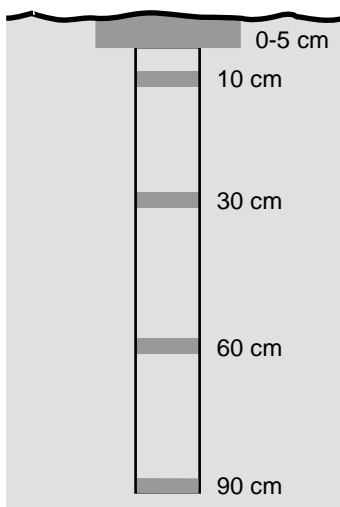


Figure SOIL-P-11



Collecting at Different Depths (5 containers, auger)

Students take measurements in a star-shaped pattern, collecting samples each time at different locations on the star. Soil samples from all five depths will be collected from the same hole. Use a trowel to sample from the top 5 cm and an auger to sample at the four deeper depths (10, 30, 60, 90 cm). Unlike the previous two sampling strategies that are designed strictly for open areas, this one can be done in the open or under a canopy, depending upon what data comparisons



you wish to make (e.g. comparing soil moisture to evaporation or

tree growth). Layout a star pattern as described above to locate the sampling holes around a central reference marker. If your auger strikes an obstruction, offset by 25 cm and try again. Depending upon conditions, a hole 90 cm deep might take 30 minutes to auger and sample.

Advanced students in areas where soils are not strongly acidic are encouraged to consider using the *Optional Gypsum Block Soil Moisture Protocol*.

Figure SOIL-P-12

Gravimetric Soil Moisture Protocol



Welcome

Introduction

Protocols

Learning Activities

Appendix

Soil Moisture and Temperature

Purpose

To measure the water content of the soil

Overview

Soil moisture samples are collected following one of three sampling strategies. In each case, there are three basic steps:

1. collecting soil samples
2. weighing, drying, and reweighing soil samples
3. data submission

Time

Up to 15 minutes to collect each sample, 15 minutes for first weighing, 15 minutes for second weighing, samples dry in oven overnight

Frequency

Twelve times per year, at regular intervals (weekly to monthly)

Level

All

Key Concepts

- Soil holds moisture.
- Soil moisture increases after precipitation, and the amount of this increase depends on many factors.
- Soil moisture decreases under dry, sunny conditions, and the rate of soil drying also depends on many factors.

Skills

- Sampling soil
- Using a balance
- Recording data

Materials and Tools

- GLOBE Science Notebooks and pencils
- Soil Moisture Data Work Sheet (Star or Transect)
- Trowel or appropriate auger
- 5-13 soil collection containers (soil sample cans, small glass jars with tight-fitting lids, etc.)
- Adhesive tape and pens with which to label the soil cans
- Soil drying oven
- Thermometer (capable of measuring to 110° C)
- Balance or scale with 0.1 g sensitivity
- Hot pad or oven mitt for removing cans of soil from ovens
- Meter stick

Preparation

- Locate the soil moisture site.
- Decide upon the sampling frequency and strategy.
- Assemble the necessary materials.

Prerequisites

- It is useful to have a rain gauge nearby and to have performed the *Soil Characterization Protocols* on your Soil Moisture Study Site.



How to Collect Soil Moisture Samples

Preparation for Collecting Samples

1. Review procedures, site sampling strategy, and layout.
2. Label each can with a unique identification number.
3. Record the location of the site and site description.
4. Locate the sampling point.

Procedures for Star and Transect Sampling

1. Note your surface cover type. Is it short grass (<10 cm), long grass, or bare soil? Scrape or pull this away. Note if there are any trees overhead or nearby.
2. Dig a hole 10 cm in diameter down to 5 cm. Leave this soil loose in your hole.
3. Sort out and remove any rocks or pebbles larger than a pea (about 5 mm) and remove any worms, grubs, or other animals.
4. Fill your soil collection container about 3/4 full with approximately 100 g of soil.
5. Number the container and record the date, time, depth and can number on your Soil Moisture Data Work Sheet. For Transect, skip to Step 9.
6. Remove the soil down to a depth of about 8 cm.
7. Dig the soil in the hole down an additional 4 cm leaving this soil in the hole.
8. Repeat steps 3, 4, and 5 for this 4 cm deep soil layer.
9. Carefully return remaining soil to the hole.
10. Seal the container and store away from heat or sunlight for transport back to the lab or classroom.
11. Take one soil temperature measurement within 25 cm of each soil sampling point at depths of 5 and 10 cm following the *Soil Temperature Protocol*.

Procedures for Depth Sampling

1. Take a sample of the top 5 cm of soil following Steps 1 - 5 as given for *Star and Transect Sampling*.
2. Auger a hole down to just above the first target depth (10 cm).
3. Use the auger to obtain a soil sample of approximately 100 g.
4. Collect the soil sample centered at the target depth.
5. Sort out and remove any rocks or pebbles larger than pea size (about 5 mm) and remove any worms, grubs, or other animals.
6. Fill a soil container about 3/4 full (about 100 g).
7. Number the container and record the date, time, depth and the container's number on your data sheet.
8. Seal the container tightly and store it away from heat or sunlight.
9. Repeat steps 1 - 8 at each depth (30, 60, 90 cm) using the same hole.
10. Carefully return the remaining soil into the hole.
11. Take three soil temperature measurements at depths of 5 cm and 10 cm within 25 cm of the sampling point.

How to Weigh and Dry the Samples

Preparation for Weighing and Drying Samples

1. Preheat the oven.
2. Calibrate the balance with a standard weight to ensure its accuracy.
3. Record the weight of the standard to the nearest 0.1 g in your GLOBE Science Notebook. The weight must be within 0.25 g of the previously recorded standard weight.

Weighing and Drying Procedure

1. Remove any tape from the can that contains the sample soil and uncover the sample.
2. Weigh the soil collection container with the soil sample in it. This is the *wet weight*.



3. Record the date and time at which the sample was collected, the container's number, and the wet weight to nearest 0.1 g on your Soil Moisture Data Work Sheet.
4. Dry the soil by placing the uncovered can in a drying oven using the following minimum conditions:
Ventilated drying oven, 95° to 105° C, 10 hours,
Dehydrating oven, 75° to 95 °C, 24 hours
Microwave oven, high power, microwave safe container only, repeated 5 minute intervals until the sample(s) do not change in weight by 0.25 g from one drying to the next.
5. Remove the can from the oven with the hot pad or oven mitts. Let it cool for five minutes.
6. Re-weigh the soil collection container with the soil in it to obtain the *dry weight*.
Note: If you are concerned that a sample is not totally dry, remove it from the oven, weigh it, and return it to the oven for 10 hours. If the weight does not decrease by 0.25 g, then it is dry.
7. Record the drying time, the type of drying oven used, and the dry weight to the nearest 0.1 g on your Soil Moisture Data Work Sheet. Calculate the water weight by subtracting the dry weight from the wet weight.
8. Empty the soil out of each container and wipe the can clean with a paper towel.
9. Weigh the dry, empty soil collection container to determine the container weight.
10. Record the container weight to the nearest 0.1 g on your Soil Moisture Data Work Sheet, and calculate the dry soil weight by subtracting the container weight from the dry weight.
11. Calculate the Soil Water Content by dividing the water weight by the dry soil weight, and record your result on the Soil Moisture Data Work Sheet.
12. Repeat steps 1 - 11 for each soil sample.

Data Submission

Report the following information to the GLOBE Student Data Server:

- Date and time of sampling
- Container number
- Depth (in cm)
- Wet weight (in grams)
- Dry weight (in grams)
- Container weight (empty, in grams)
- Drying method (select one of: 95-105 C oven, 75-95 C oven, Microwave)
- Average drying time (in hours and/or minutes)
- Current conditions: Is the soil saturated? (select either YES or NO)
- Station spacing of your transect, if used

Students can calculate the soil water content (SWC) defined below, or let the GLOBE Student Data Server make this calculation. Making this calculation and entering it on the Data Entry Sheet is helpful as a quality control check. If the SWC calculated by students is different by more than 1% from the value calculated by GLOBE, a warning message will appear. In this case, students should make sure that the weights were entered correctly and check their calculations.

In addition, please enter the following information using the Define a Soil Moisture Study Site Data Entry Sheet:

- GPS location of the study site (the center of the star, gypsum block hole, or reference marker at one end of the transect)
- Distances and directions to other related sites (rain gauge, max-min thermometer, closest soil characterization sample location)
- How would you describe the surface of your site? Select one: natural, plowed, graded, backfill soil, compacted soil, or something else (other)
- How would you characterize the surface cover? Select one, Primarily: bare soil, short grass (<10 cm), or long grass (>10 cm)



- How would you describe the canopy cover? Select one: Open, Some trees within 30 m or Canopy overhead (answer this question assuming growing season conditions)
- Soil classification (using the Soil Characterization Data Entry Sheet for these data)
Describe and report as many soil characteristics as possible following the protocols in *Part One* of this investigation.
- Land Cover classification
Classify your Soil Moisture Study Site as instructed in the *MUC System Protocol* and report the Level 4 MUC code and land cover name.



Optional Gypsum Block Soil Moisture Protocol



Welcome

Introduction

Protocols

Gravimetric Soil Moisture

Learning Activities

Appendix

Purpose

To measure the water content of the soil based on the electrical resistance of gypsum blocks

Overview

The Gypsum Block Protocol consists of:

1. installing gypsum blocks at 10, 30, 60, and 90 cm depths
2. reading the soil moisture meter
3. calibrating the gypsum blocks
4. creating a calibration curve

Time

10 minutes per day

Initial calibration requires doing the Gravimetric Soil Moisture Protocol for the 30 cm depth about 20 times over six to eight weeks.

Level

Advanced

Frequency

Daily

Re-installation and calibration of gypsum blocks should be done annually.

Key Concepts

A Gypsum block's electrical resistance is related to soil moisture and is a function of its wetness.

Local conditions affect the saturation of gypsum blocks and requires us to calibrate them.

Soil moisture increases after precipitation.

The amount of increase in soil moisture after precipitation depends on many factors.

Soil moisture decreases on dry, sunny days.

The rate of soil drying depends on many factors.

Skills

Sampling soil

Using a balance

Using a soil moisture meter

Recording data

Materials and Tools

Auger

Meter stick

Four gypsum blocks

Four 10 cm long x 7.6 cm diameter PVC tube or tin cans for wire holders at the surface

Two 4-L soil holding/mixing buckets

Water for making mud balls (1 L)

One 1 m x 2 cm PVC guide tube

Soil packing stick (e.g. an old broom handle)

GLOBE Science Notebooks and pencils

Soil moisture meter

Graph paper

Calculator

Materials for the *Gravimetric Soil Moisture Protocol*

Preparation

Locate the soil moisture site.

Determine and report the requested soil moisture site metadata.

Collect the tools and materials.

Prerequisites

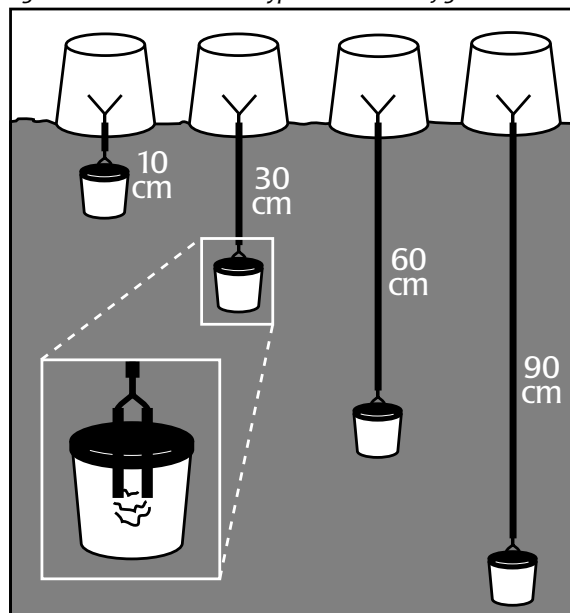
It is useful to have a rain gauge nearby and to have performed the Soil Characterization protocols at your Soil Moisture Study Site.



Installation of Gypsum Blocks

1. Place the gypsum blocks into a container of water and soak for 5 minutes.
2. Auger a hole to the appropriate depth for each gypsum block sensor (10, 30, 60 and 90 cm). A soil auger works like a cork screw - simply lean on the handle as you turn it. It is best to remove the auger bucket from the hole after each 360° turn and clean the soil out of the bucket. If you fill it too full, it will be very difficult to remove the soil. Place the extracted soil in a large pail to keep the site clean. The four holes should be placed next to one another in sequence to reduce potential confusion while taking readings and recording data.
3. Put two large handfuls of the soil extracted from the hole into a small bucket or similar container. Add a small amount of water and stir to create a mud ball. The mud ball should stick together. Remove any rocks.
4. Drop the mud ball to the bottom of the hole. Make sure it reaches the bottom.
5. Place the wire lead from one of the sensors through the PVC guide tube.
6. Grab the end of the lead and pull the sensor up tight against the end of the pipe. Lower the sensor into the hole while holding it against the end of the pipe. Holding the wire lead tightly at the top of the pipe, gently push the pipe down to seat the sensor in the mud at the bottom of the hole. Note: Since it is difficult to pack soil tightly around the sensor, the purpose of the mud is to establish good contact between the sensor and the soil particles.
7. Hold the sensor in place with the pipe while you begin to backfill the hole. Add just a few handfuls of soil and gently tamp with a broom stick or similar pole. Then add a little more soil and remove the pipe as you tamp. Continue adding soil a few handfuls at a time and tamping firmly as you backfill the hole. Hold on to the wire lead as you backfill so that it will come straight to the surface.

Figure SOIL-P-13: Installed Gypsum Blocks Configuration



8. Place a short piece (about 10 to 20 cm long) of PVC pipe, tin can, or coffee can (with the top and bottom removed) around the wire lead at the surface to protect it and make it more visible to anyone walking in the vicinity.
 - 8.1. First, label the pipe or can with the appropriate sensor depth.
 - 8.2. Put the wire through the pipe or can and press the pipe or can 2 to 5 cm into the soil to keep it in place. Do not cut the wire, but wind up the free end extending out of the ground and place it in the pipe or can to keep it out of the way between measurements.
 - 8.3. A small empty can (soup, etc.) should be inverted over the end of the PVC pipe to keep the rain out.
9. Repeat the above steps for each sensor.

Do not report measurements for a week after installation. The sensors require at least one week to equilibrate to natural conditions. The wire leads are fragile, especially where they connect to the meter. If the end of the wire leads to the gypsum blocks break, peel back the wire insulation and make new leads. It is important to leave enough wire above the ground for this.

Reading the Soil Moisture Meter

Congratulations! Your gypsum blocks are installed. Wait at least one week before beginning to take data which you report to the GLOBE Student Data Archive. After this, monitor your gypsum blocks daily for soil moisture variations. This is the fun and easy part of this investigation. Do not monitor the blocks when the ground is frozen.

Preparation

Test the soil moisture meter to ensure it is functioning properly according to the manufacturer's instructions. Do this before each use.

How to Make a Soil Moisture Reading

1. Obtain the reading for each gypsum block.
 - 1.1. Connect the soil-moisture meter to the wire leads of the gypsum block located at the 10 cm depth.
 - 1.2. Push READ button. Wait for the meter to reach a constant value - it should not be negative.
 - 1.3. Record the date, time, current soil conditions (CC's), and soil moisture meter reading on the Daily Gypsum Block Data Work Sheet in the appropriate depth column.
 - 1.4. Disconnect the meter and store the wire leads.
 - 1.5. Replace the cover over the PVC pipe.
 - 1.6. Repeat a - e for each of the remaining gypsum blocks (30, 60, 90 cm).
2. Report all four meter readings to the GLOBE Student Data Server.
3. Convert each meter reading to soil water content using the calibration chart.

How to Use the Daily Gypsum Block Data Work Sheet

There are numbers 1 to 0 in the far left column. Please keep a running count of your measurements by adding a tens digit as you accumulate more data. This allows someone reviewing your data sheets to ascertain if any pages are missing. There is also space to plot your data in the field as you collect it. You would normally expect gradual transitions except for the rapid increase in soil moisture after a rain.

Calibration of Gypsum Blocks

The gypsum blocks must be calibrated so that the meter reading you make can be related to soil water content (SWC). This process can take 6-8 weeks, depending upon how quickly your soil moves through its full drying cycle. Rather than calibrate your gypsum blocks at every depth, we have adopted a policy of basing each calibration on observations made from the 30 cm sensor. Technically, this assumes your soil profile is uniform and your gypsum blocks are identical. It takes about 30 minutes to complete the steps below. You may calibrate your gypsum blocks at 10, 60, and 90 cm depths using the same procedure if you wish.

What To Do and How To Do It

1. Take a soil meter reading from the 30 cm gypsum block sensor.
2. Select a random location within 5 m of the gypsum block hole.
3. Clear surface debris.
4. Auger to 30 cm and collect a 100 g sample centered at this depth. Place the soil sample in a container and number the container.
5. Backfill the hole and replace the surface cover.
6. Record the date, time, depth and container number.
7. Follow the instructions for *Weighing and Drying The Samples* found in the *Gravimetric Soil Moisture Protocol* and make a note of your drying method and average drying time.
8. Record on the Annual Gypsum Block Calibration Data Work Sheet the date and time of your measurement, the wet, dry, and container weights and the soil moisture meter reading that you obtained. There is also space to calculate soil water content (SWC).
9. Repeat steps 1 - 8 about twenty times as the soil moves through one or two complete drying cycles. Wait until your meter reading changes 5% before collecting another gravimetric sample. Re-install and recalibrate your gypsum blocks once a year.



Creating a Calibration Curve

How to plot a calibration curve

1. Complete the Annual Gypsum Block Calibration Data Work Sheet using the following formula to calculate the values for Soil Water Content (SWC) for each row of the Work Sheet.

$$\text{SWC} = \frac{(\text{wet weight} - \text{dry weight})}{(\text{dry weight} - \text{can weight})} \times 100$$

Remember:

wet weight = wet soil + can

dry weight = dry soil + can

2. Create a graph in which you plot all the soil water content data collected on the Y-axis and all the corresponding soil moisture meter readings on the X-axis. Draw or calculate the *best-fit quadratic curve* through your data pairs, which should span a broad range of soil moistures. This will be your calibration curve, which you will use to convert other meter readings to soil water content.

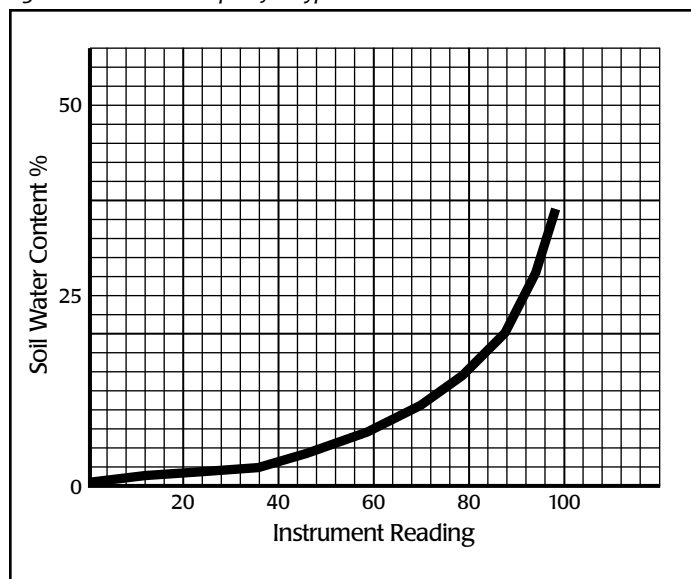
If you have any questions about creating your calibration curve or if you need any assistance with the curve, the principal investigator for the *Soil Moisture Investigation* is glad to provide answers and assistance and can be contacted at the addresses given in the *Welcome Section*.

When you have finished determining your calibration curve, please mail or email a copy of your curve and of your corresponding Annual Gypsum Block Calibration Data Work Sheet to GLOBE Student Data Archive at the address given in the *Implementation Guide*.

During the year, if you get readings either higher or lower than any of the readings on your Data Work Sheet, take a gravimetric sample, and use the values you measure for this sample to extend your calibration curve. Send a copy of your revised calibration curve and extended Annual Gypsum Block Calibration Data Work Sheet to the GLOBE Student Data Archive.



Figure SOIL-P-14: Example of a Gypsum Block Calibration Curve



30 cm

Date	Reading	SWC
2/4/97	42	7
2/25/97	17	3
3/6/97	96	35
3/8/97	91	25
3/18/97	70	14

Infiltration Protocol



Welcome

Introduction

Protocols

Learning Activities

Appendix

Optional Gypsum Block

Purpose

To determine the rate at which water soaks into the ground as a function of time

Overview

Two nested cans are pushed into the soil and water is added to both to a depth of at least 5 cm. The time it takes water to drop a fixed 2 - 4 cm distance is recorded and the measurement is repeated. Infiltration measures how easily water moves vertically through the soil and this can indicate how flood-prone an area is.

Time

One class period to build and test the double-ring infiltrometer

45 minutes or one class period for the measurement

This protocol can be done while samples are collected for the *Gravimetric Soil Moisture*

Level

All

Frequency

Three or four times a year at the Soil Moisture Study Site

One time at a Soil Characterization Sample Site

In all cases three sets of measurements should be taken within a radius of 5 m.

Key Concepts

Infiltration rate changes depending upon the level of soil saturation.

If water is not stored in the ground, it must evaporate or runoff and may pool on the surface for a time.

Skills

Building an infiltrometer

Testing

Organizing

Observing

Monitoring time intervals

Recording data

Analyzing data

Materials and Tools

Two metal rings the smaller with a diameter of 10 - 20 cm and the other with a diameter 5 - 10 cm larger (Coffee cans work!)

Buckets or other containers to transport a total of at least 8 L of water to the site

Ruler

Waterproof marker

Stop watch or watch with a second hand

Block of wood

Hammer

Three soil sample containers suitable for soil moisture measurement

Grass clippers

Funnel

Prerequisites

None



Background

Infiltration rate is determined by measuring the time it takes the level of water sitting on a soil to drop a fixed distance. This rate changes with time as the soil pore space fills with water and reaches a steady rate, characteristic of water flow through your soil when it is *saturated*. There are three flow regimes you might encounter:

Unsaturated flow - the initial flow rate is high as the dry soil pores fill with water.

Saturated flow - the flow rate is steady and water moves into the soil at a rate determined by soil texture and structure.

Ponding - the flow rate approaches zero when the ground becomes totally saturated and is no longer able to conduct water through its pores.

Preparation

Site selection

Select a location within 2 - 5 m of the Soil Moisture Study Site or of a Soil Characterization Sample Site. Be careful that you do not leave a hose running where the water will flow over your soil moisture sampling points!

Construct a Dual Ring Infiltrrometer

Cut the bottom out of your cans.

Use a permanent waterproof marker or paint to partially shade a ring on the inside of the smaller can to use as a timing reference mark. The width of the band or ring should be 20-40 mm and centered roughly 9 cm from the bottom of the can. Many cans have impressed ribs that make good reference marks but it is still necessary to mark them for good visibility.

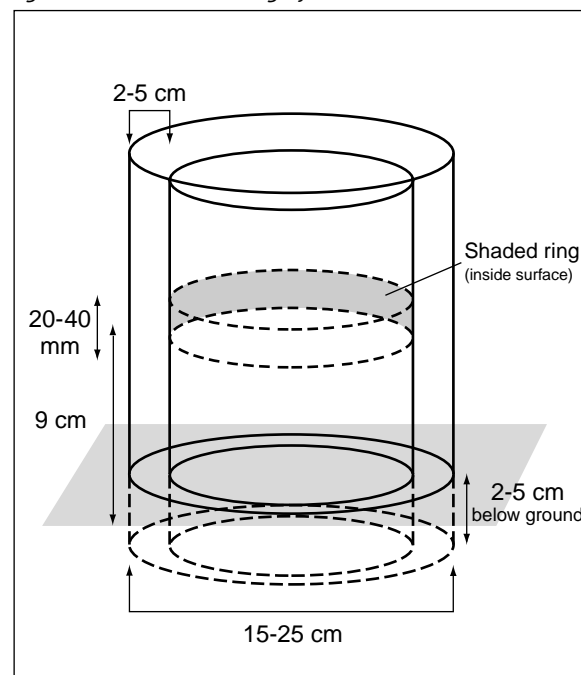
Measure and record the width of your reference band (in mm).

Measure and record the widths of your inner and outer rings (in cm).

Timing

You can use either a stop watch or a watch with a second hand to time the water flow into the soil. When using a stop watch, start it as water is first poured into the inner ring and read elapsed time from it for each start time and end time.

Figure SOIL-P-15: Double-ring infiltrrometer



Practice

Have students practice this protocol, including the timing, so that they become comfortable making the measurements at a site where there is easy access to water and at a time when they can start over and do not have to complete a full 45 minute set of measurements. If students practice in a sandy location, the infiltration time intervals will be shorter and they will get more chances to make measurements.

How to Measure Infiltration

1. Clip any vegetation (grass) to the ground surface and remove all loose organic cover over an area just larger than your largest can. Try not to disturb the soil.
2. Starting with the smaller can, twist the cans 2 - 5 cm into the soil. A hammer may be used to pound the can into the surface. If you must use a hammer, a block of wood should be used between the hammer and the top of the can to distribute the force of the hammering. Do not hammer so hard that the can crumples.

3. Measure the height above ground level of the bottom and top of the band you marked on the inside of the smaller can.
4. As quickly as possible, do the following using a team of 3 - 4 students:
 - 4.1. Pour water into both rings, and maintain a level in the outer ring approximately equal to the level in the inner ring. Note that the water level in the outer ring tends to drop more quickly than that of the inner ring.
 - 4.2. Pour water into the inner ring, to just above the upper reference mark.
 - 4.3. Start the stopwatch or note the time to the second and record it on the Infiltration Data Work Sheet.Note: The outer ring should not be leaking water to the surface around its rim. If it is, start over in another location, push the outer ring deeper into the soil or pack mud around its base.
5. As the water level in the inner ring reaches the upper reference mark, record the elapsed time as your start time.
6. During the timing interval, keep the water level in the outer ring approximately equal to the level in the inner ring, but be careful not to pour water into the inner ring (using a funnel can help) or to let either ring go dry.
7. As the water level in the inner can reaches the lower reference mark,
 - 7.1. Record the time as your end time.
 - 7.2. Figure the time interval by taking the difference between the start and end times.
 - 7.3. Pour water into the inner ring to just above the upper reference mark. Raise the water level in the outer ring so that they are approximately equal.
8. Continue repeating steps 5 - 7 for 45 minutes or until two consecutive interval times are within 10 sec. of one another.
9. Some clays and compacted soils will be impervious to water infiltration and your water level will hardly drop at all within a

45-minute time period. In this case, record the depth of water change, if any, to the nearest mm. Record the time at which you stopped your observations as the end time. Your infiltration measurement will consist of a single data interval.

10. Remove the rings. WAIT FIVE MINUTES.
11. Measure the near-surface (0 - 5 cm depth) soil moisture from the spot where you just removed the rings. Follow the *Gravimetric Soil Moisture Protocol*.
12. Make two other infiltration measurements within a 5 m diameter area, either at the same time using other groups or over several days (if it does not rain and change near-surface soil water content). It is not critical that multiple runs have the same number of reading sets, but do not submit runs that are incomplete (e.g. A run that was cut short due to lack of time). If you make more than three sets of measurements, submit your three best sets.

Data Analysis and Presentation

Infiltration rate is found from the distance that the water level decreased divided by the time required for this decrease. For your GLOBE measurements this is equal to the width of your reference band divided by the difference between the start and end times for an interval.

Use the Infiltration Data Work Sheet to record and help calculate the values needed to plot your results. The flow rate we observe for each timing interval is really the average value during that interval. It is best to plot that flow rate at the *midpoint* of the interval times. Infiltration should decrease with time and it is important that you keep track of the *cumulative* time since water was first poured into the inner ring. Look over the table and graph below and make sure that you can use the formulas on the Data Work Sheet to calculate these values before analyzing your own data.



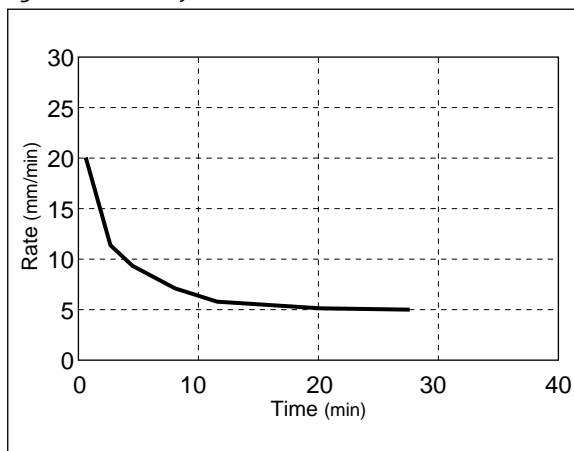
Figure SOIL-P-16
Infiltration into Jim's Garden

Water Level Change = 20 mm

Time						Flow	
Start		End		Interval	Midpoint	Cumulative	Rate
[min]	[sec]	[min]	[sec]	[min]	[min]	[min]	[mm/min]
31	00	32	00	1.00	31.50	0.50	20.0
32	30	34	15	1.75	33.38	2.38	11.43
34	30	36	45	2.25	35.62	4.62	8.89
37	15	40	00	2.75	38.62	7.72	7.27
40	45	44	00	3.25	42.38	11.38	6.15
44	15	47	45	3.50	46.00	15.00	5.71
48	15	52	00	3.75	50.12	19.12	5.33
52	15	56	15	4.00	54.25	23.25	5.00
56	30	00	30	4.00	58.50	27.50	5.00



Figure SOIL-P-17: Infiltration



Soil Temperature Protocol



Welcome

Introduction

Protocols

Soil Temperature

Learning Activities

Appendix

Purpose

To measure near-surface soil temperature
To detect diurnal changes in soil temperature
To learn about the insulating capabilities of the soil

Overview

Soil Temperatures at 5 and 10 cm depths will be measured using a probe thermometer. Soil temperature is a function of climate, soil, soil moisture, depth and geographic setting. This protocol collects data to explore these interactions.

Time

10-15 minutes per measurement set
(6 probe measurements)

Level

All

Frequency

Weekly: three measurements each at 5 and 10 cm depths

Seasonally: one measurement each at 5 and 10 cm depths every 2 to 3 hours during the daytime on two consecutive days

Key Concepts

Soil is an insulating layer.
Soil temperature varies with depth, soil moisture, and air temperature.
Soil temperature varies less than air temperature.

Skills

Reading dial scales
Field sampling
Observing related phenomena
Graphing temperature cycles

Materials and Tools

Dial or Digital probe thermometer
12 cm finishing nail and hammer
A wooden block with 6 mm diameter hole through it
Calibration thermometer

Preparation

None

Prerequisites

None

Site Selection and Timing

Make measurements adjacent to your Soil Moisture Study Site, or if this is not possible, within 10 m of your Atmosphere Study Site. Study the figures of the star or transect sampling patterns described in the *Sampling Strategies* and *Site Layout* sections which illustrate acceptable sampling locations. If you are making these measurements at your Atmosphere Study Site, follow the sampling pattern and site layout for the Star Pattern.

1. Select a relatively flat sunny area.
2. Try to find an area with uniform characteristics across an area having a diameter of 5 m.
3. The ground should not be compacted but can be covered with litter or grass.
 - Make a note on the Data Work Sheet if it has rained in the past 24 hours.

When making measurements on consecutive days, try to make your readings on days with similar weather conditions and for soil conditions that are typical for the week you are making them. Try to make diurnal readings around the middle of March, June, September, and December.



Preparing for the Field

Your thermometer should be most sensitive to temperature changes about 2 cm from the tip because of the length of the temperature sensor inside the probe. To take measurements at 5 and 10 cm depths, the thermometer will have to be pushed 7 and 12 cm into the ground.

Drill a hole in a wooden block so that when the soil thermometer is pushed all the way into this hole 7 cm of your probe extends beyond the bottom of the block. This will help students maintain a uniform depth for the 5 cm depth measurements.

Get a nail that is the same length and diameter as your thermometer probe or cut a nail to this length.

Calibration:

Check the accuracy of your probe every three months. This is particularly important if you are using more than one thermometer, as differences or biases between two thermometers will make your data impossible to interpret. Follow this calibration procedure:

1. Use the calibration thermometer from the Atmosphere Investigation as a calibration standard.
2. Place your thermometers in water at room temperature; record their temperature readings after 2 minutes.
3. There should be less than 2° C difference between your thermometer readings and the calibration thermometer.
4. Follow the manufacturer's directions to reset dial-type thermometers, if your differences are greater than this.

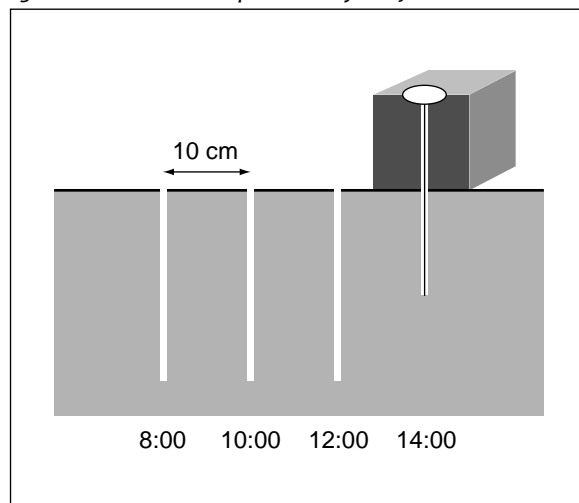
How to Measure Soil Temperature

1. Make a pilot hole to 5 cm. Insert the nail through your wood block and push it to 2 cm above the top of the block. If the ground is so hard you have to use a hammer, then complete the pilot hole to its full depth. Remove the nail using a twisting motion. If the ground cracks and bulges up as you remove the pilot nail,

offset 25 cm and try again. Try to minimize the amount you disturb the soil.

2. Insert the thermometer to 7 cm. Insert the thermometer through your block. Gently push and twist the thermometer until the head is resting on the block. Do not force it as this will damage your instrument.
3. Read the soil temperature at 5 cm. Wait at least 2 minutes; read the thermometer. Wait another minute, and reread the thermometer. Repeat until consecutive readings are within 0.5 - 1.0° C of each other. Record this value on the Soil Temperature Data Work Sheet.
4. Remove the thermometer and the block. Use a twisting motion - try not to disturb the soil.
5. Repeat steps 1-4 without the wood block. Gently push and twist your thermometer fully into the ground using the same hole as before. Instead of depths of 5 and 7 cm, use depths of 10 and 12 cm, respectively.
6. Report your measurements to the GLOBE Student Data Server on the Soil Temperature Data Entry Sheet.

Figure SOIL-P-18: Soil Temperature: Layout of Diurnal Observations



Weekly Measurements

Take three sets of soil temperature measurements adjacent to your current soil moisture star pattern sampling location or next to your Atmospheric weather shelter at 5 and 10 cm depths. Complete these measurements within 1 hour of local solar noon and within a period of 20 minutes. Record your time to the nearest 10 minutes (e.g. if you take the 5 cm reading at XX:06, select the next 10 minute mark, XX:10, as your time of observation).

Diurnal/Seasonal Measurements

Take diurnal temperature measurements every three months, preferably during March, June, September, and December. Repeat the measurements every 2 to 3 hours on two consecutive days. Try to take at least 5 readings per day. Offset each new reading by at least 10 cm. See Figure SOIL-P-19. Read the current temperature at your Atmosphere Investigation Instrument Shelter and record it in your GLOBE Student Notebook each time you measure soil temperature.

Data Analysis and Presentation

Construct a table in your GLOBE Student Notebook similar to the one below for recording your results or use the Soil Temperature Data Work Sheet. Plot the data using Figure SOIL-P-20 as a guide.

Figure SOIL-P-19: Soil Temperatures Tucson, AZ

	2/12/97		2/13/97		ND=no data
Local Time	5 cm	10 cm	5 cm	10 cm	Air Temp
8:00	ND	ND	ND	ND	ND
10:00	9.5	9.1	8.7	9.5	ND
12:00	17.8	13.0	10.7	10.5	26.2
14:30	20.6	16.5	12.9	12.0	ND
17:00	16.8	16.3	13.6	14.0	ND
20:30	13.0	13.9	11.9	13.0	ND

Figure SOIL-P-20: Soil Temperatures

